



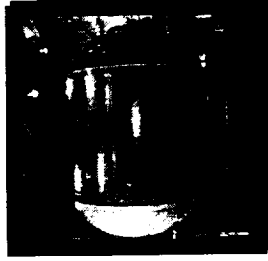
Emerging Composite Technologies

- Lockheed Martin Space Systems Co. - Michoud Operations Overview
- External Tank Composite Applications
- Composite Development
 - Cryogenic Tankage
 - Composite Repair
 - Cryogenic Feedlines
 - LO2 Compatible Composites
- National Center for Advanced Manufacturing (NCAM)
- Summary

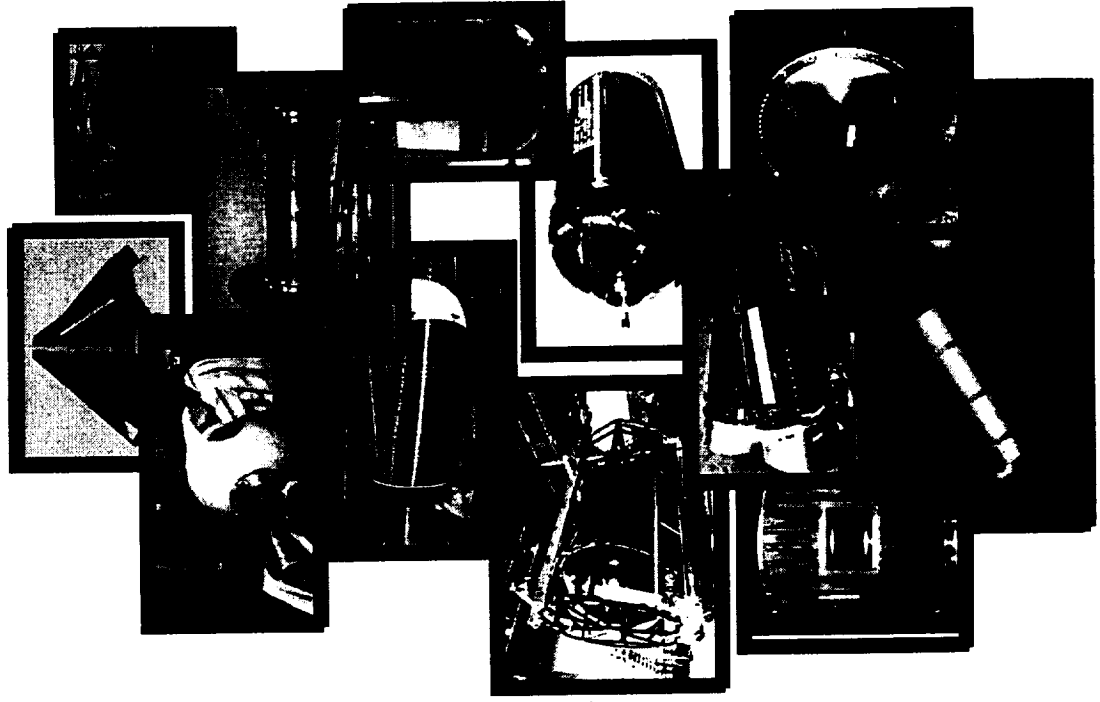
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Michoud Operations Overview

Expanding from metals into composites



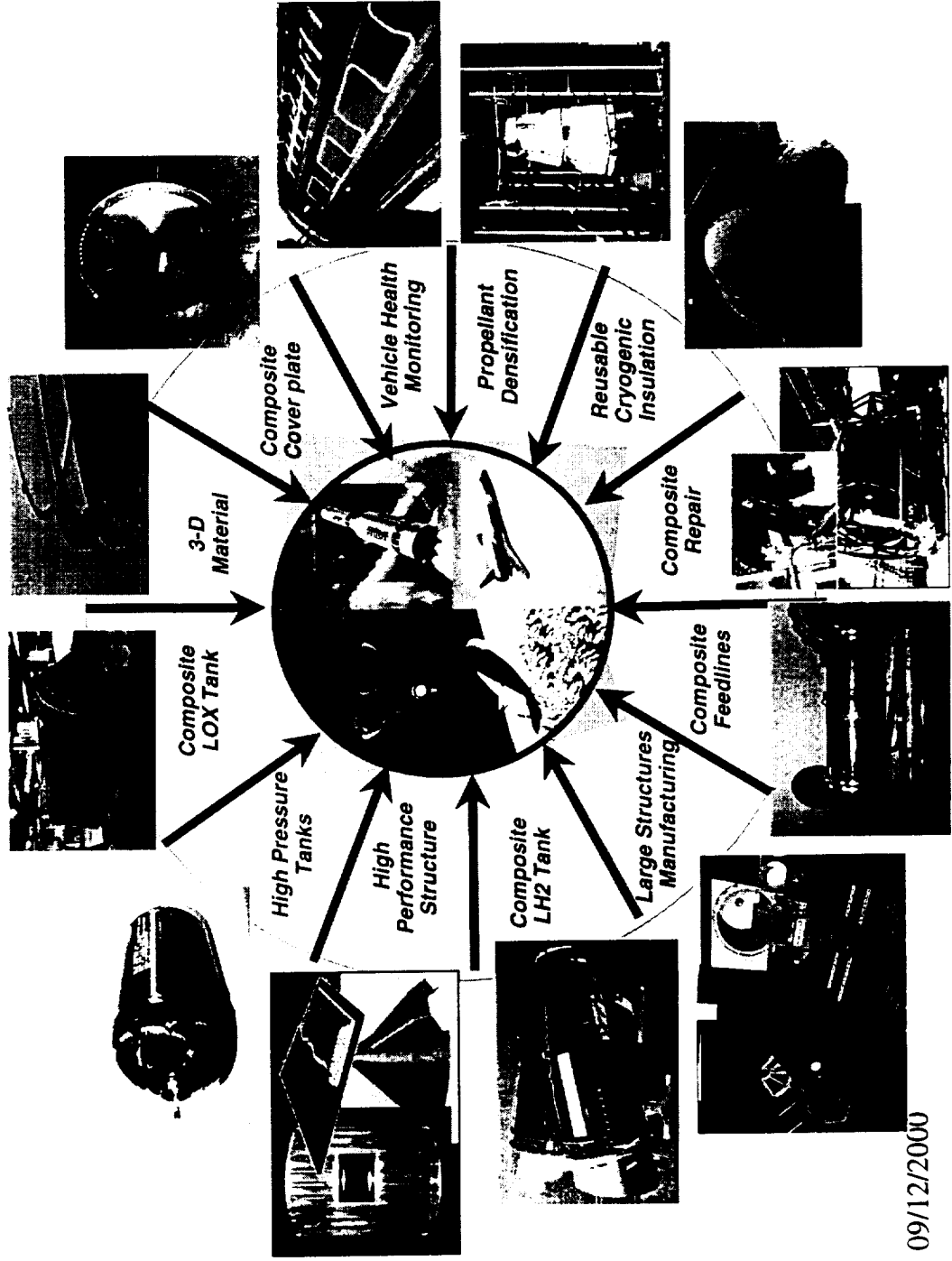
*Over 25 years cryogenic
structures experience*





Michoud Operations Overview

Emerging composite technologies

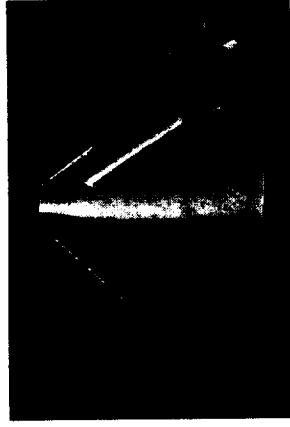


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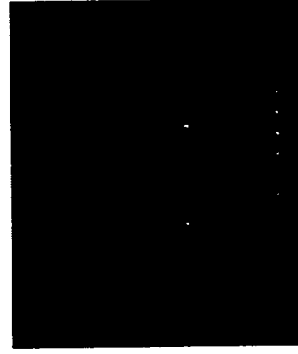
External Tank Composite Applications



Fwd GH2 Pressline Fairing
Graphite/epoxy



Nose Cone
Graphite/phenolic
Patented process



Intertank Access Door
Graphite/polyimide

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External Tank Composite Applications

Intertank development: Demonstrated the use of composite materials in a highly loaded primary structure and interface of composites with aluminum cryogenic tank

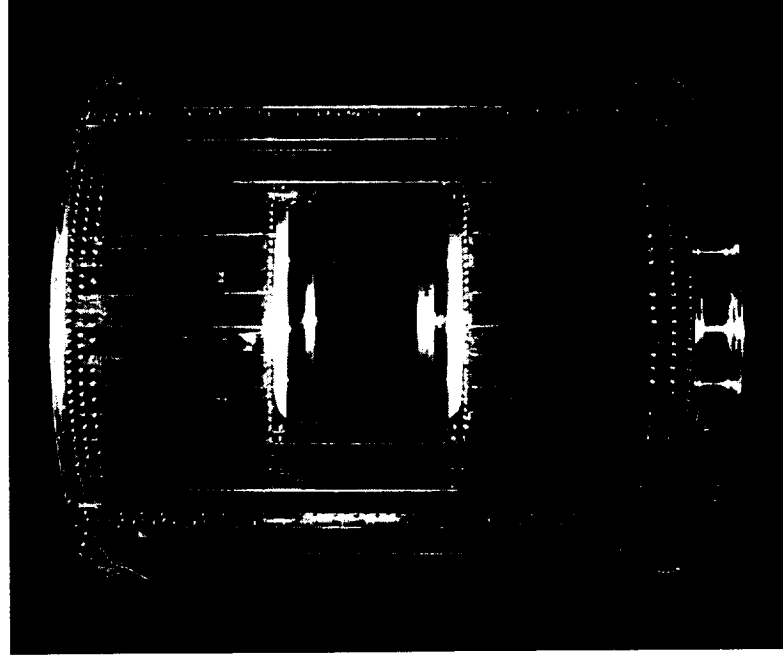
- Low cost design-to-manufacture
 - Automated processing
 - Fabrication/assembly tooling
 - Thermography NDE

Configuration typical of interfacing with aluminum cryogenic tanks

- Graphite/Epoxy panels
- Two 25" x 29" cutouts

Successful full scale test

- Verified stress/thermal analysis
- Achieved 112% of design load
- 4000 lb/in demonstrated

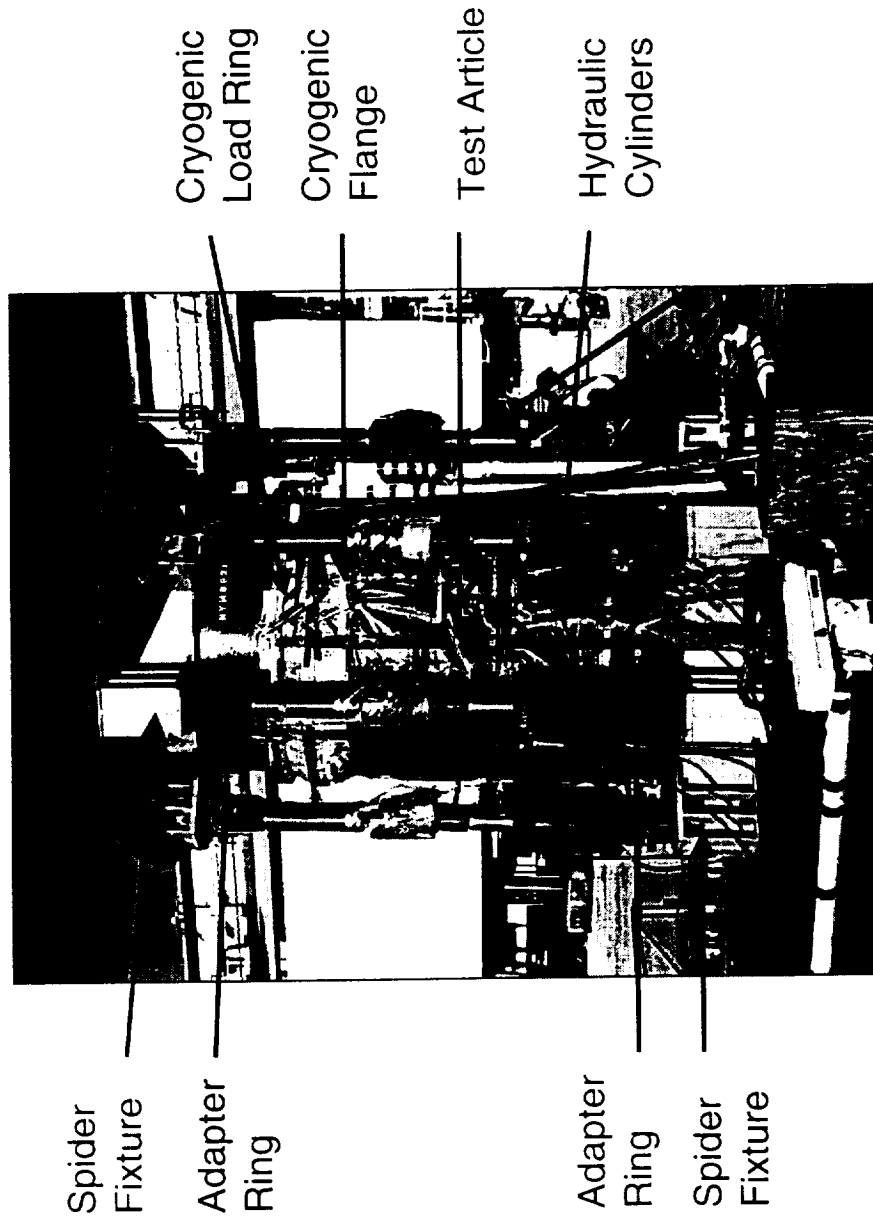


6 ft diameter x 7 ft long Intertank

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External Tank Composite Applications

Intertank performed to 223% of limit load



Cryogenic + Axial Load Test Setup

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Cryogenic Tankage



1995 - 3 ft x 6ft composite LH2 tank



- First fiberplaced composite tank to contain under high strains
- 13 cryogenic pressurization cycles on subscale tank program
- Leak free fittings/bosses
- High strain cryogenic instrumentation methods
- Reusable insulation systems
- Leak detection methodologies

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Cryogenic Tankage



1996 - Fast track composite LH2 tank technology test bed:
Design, tooling, fabrication, and test in 12 Months

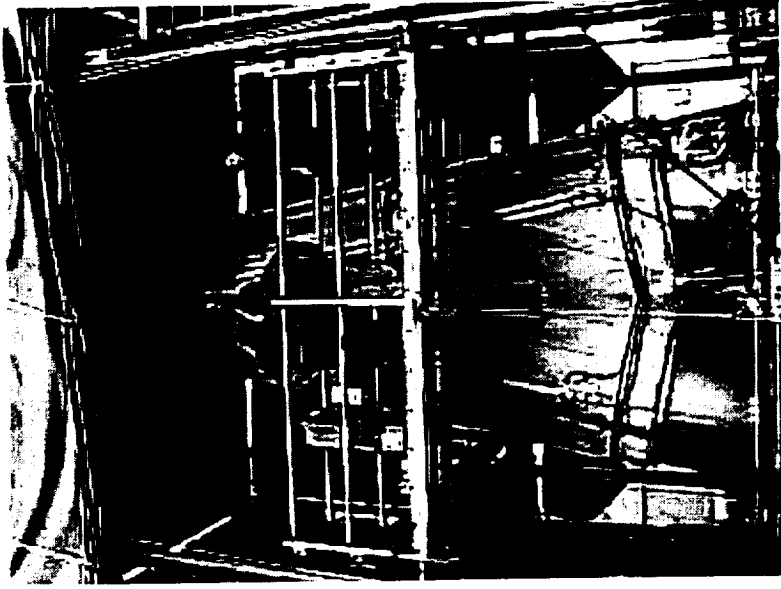


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Cryogenic Tankage



Composite LH2 tank technology test bed



Completed 78 LH2 cryogenic pressurization cycles, 8 densified hydrogen cycles to date

Demonstrated tank system capability to perform under cryogenic cycling

- Design features
- Material systems
- Health monitoring

Generated database for LH2 and densified hydrogen containment of tank laminate, joints, and repair methods

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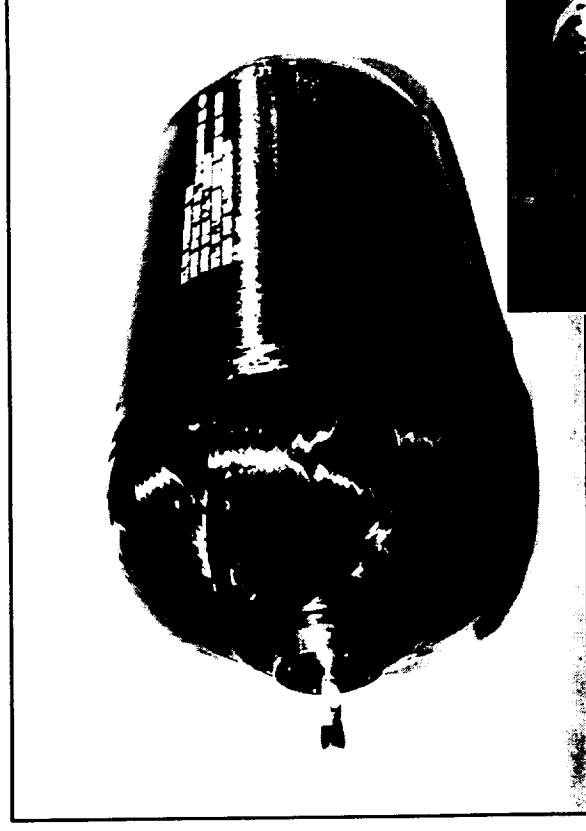
Cryogenic Tankage

Helium Pressurant Tank

Graphite / Epoxy overwrap
with thin Titanium liner

16 in. dia. x 31 in. long,
5000 cubic inches, 32 lbs typical
4800 psi operating pressure (satellite
applications), 7200 psi design burst
(9368 psi test)

Successful LH2 cycling: Qualified for
storage of cryogenic helium for tank
pressurization - significant system
weight savings over autogenous
pressurization



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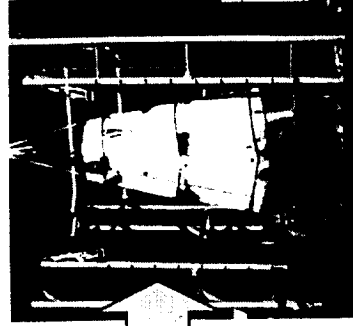


Composite Repair

Developed and demonstrated repair of composite LH2 tanks



Composite LH2 tank test
bed developed repair
techniques



Repair techniques were proven to repair
liquid and vapor leakage on full scale
tanks

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Cryogenic Feedlines

Successfully tested full scale LO2 feedline

Designed, fabricated and tested 17" composite LO2 feedline in 1999

Integral composite flanges

Low cost reusable mandrel tooling

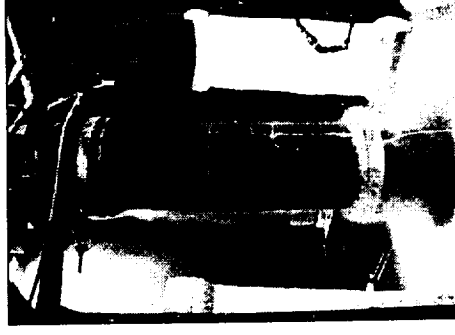
LO2 compatible material system

50 cryo cycles with pressure and loads
LN2 (-320°F), up to 255 psi + 70 KIP axial load
127 KIP flange load
2300 microstrain at max load
Full loads set

17% weight savings (22 lbs./20') over aluminum

No leakage or structural damage

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Cryogenic Feedlines

Reusable composite LO2 feed/vent lines

Designed and fabricated composite LO2 tank internal lines

Low cost expendable mandrel tooling

LO2 compatible material system

INTERNAL PROPELLANT
TRANSFER AND VENT LINES



Composite LO2 line erosion testing

Designed, fabricated and tested .625" ID LO2 compatible composite 90° tube

Unique low cost expendable tooling

11 cycles 40 psi @ 37 gal./min.

No erosion detected

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.625" ID COMPOSITE TEST ARTICLE



TEST SET UP





LO2 Compatible Composites

Continue to pursue material enhancements with superior performance and no loss of LO2 compatibility

Testing Categories

Short Beam Shear

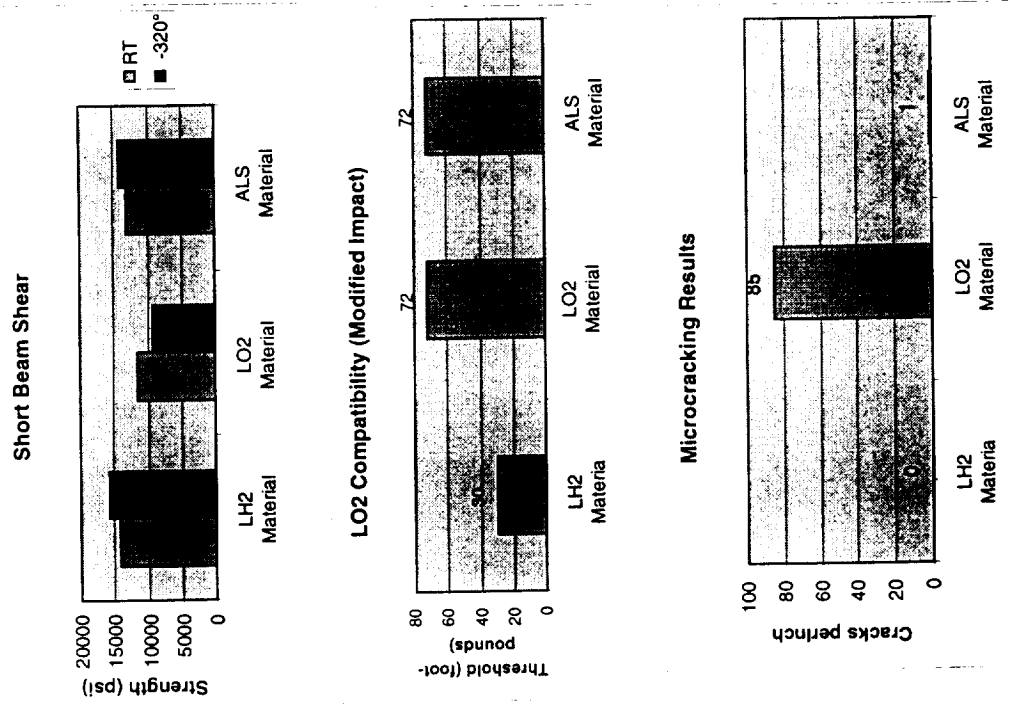
LO2 Compatibility

Thermal Cycling / Microcracking / Permeation

Tested 6 composite formulations
Mechanical and LO2 compatibility tests

Selected best structural performance with LO2 compatibility

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LO2 Compatible Composites

Standard Mechanical Impact Testing

- 0/20 Threshold
- Bruceton Up and Down Level
- 5/20 Reaction Level

No significant change in reactivity seen through 21 weeks of continuous LO2 exposure

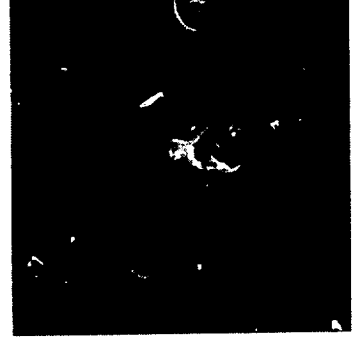
No significant chemical or surface changes in LM analysis

- XPS, XRF
- SEM

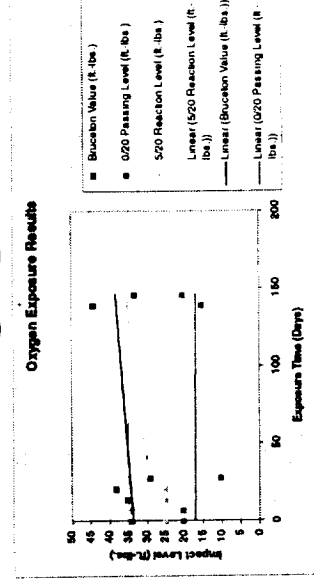
Typical Unaged
Composite Surface
(2,500X)



Typical 21 Week Aged
Composite Surface
(2,500X)



LO2 Aging Study

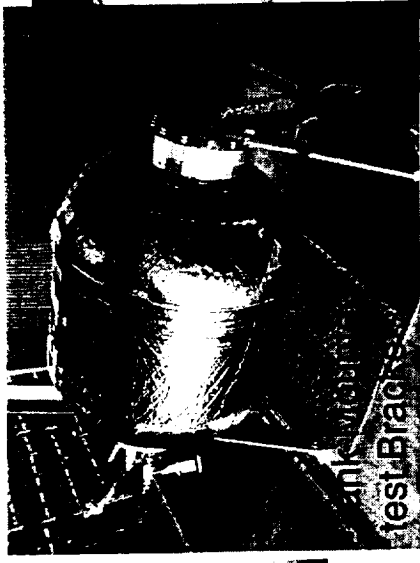
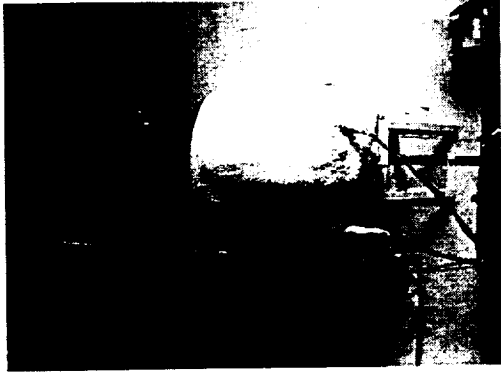


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LO2 Compatible Composites



Vibration testing of proprietary LO2 tank system
has been successfully completed



Tank tested at various fill levels

Tested with and without mechanical debris

No reactions or leakage

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NCAM

NASA Infrastructure



Michoud Assembly Facility



LA State Funded Equipment

Academia - UNO

U.S. Industry - LMMSS



MSEC at Huntsville, Alabama
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NCAM - Teammate Roles

NASA

- MSFC (Lead)
- Infrastructure / Equipment Use
- Matching Funds
- Materials Research & Technology

State Government

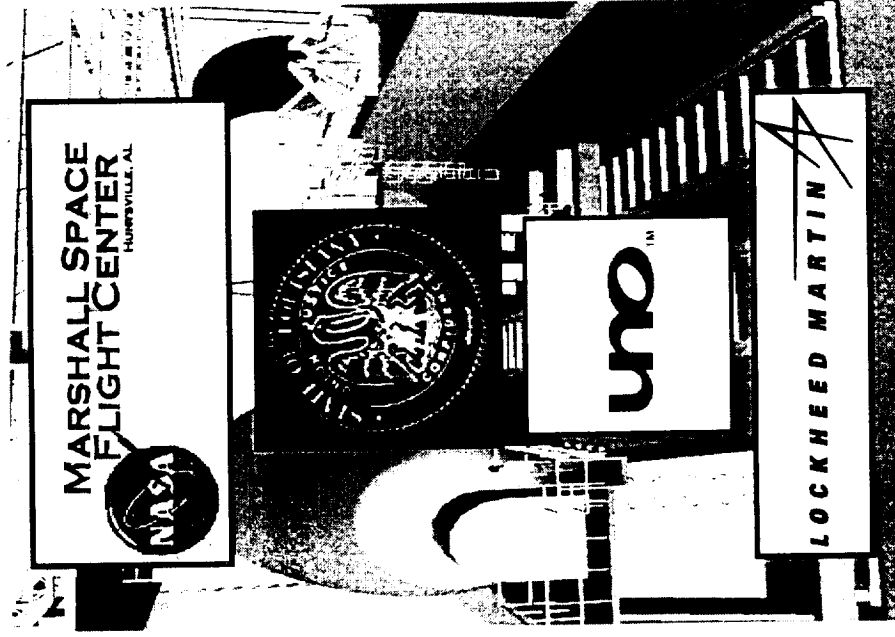
- Louisiana (Lead) Project Funding

Academia

- University of New Orleans (Lead)
- Advanced Manufacturing Research
- Workforce Skills Development
- University Consortium

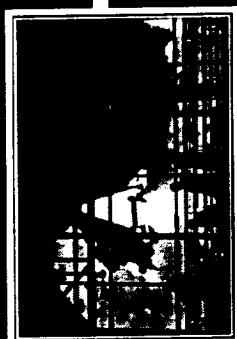
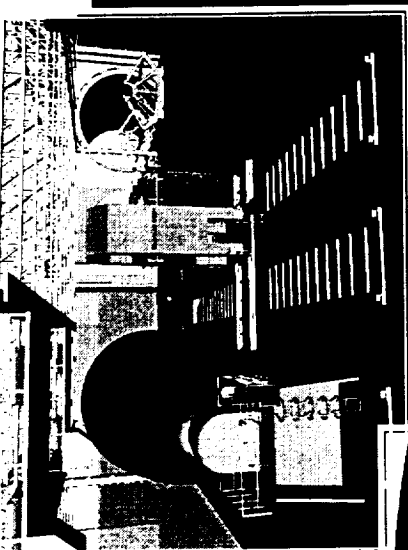
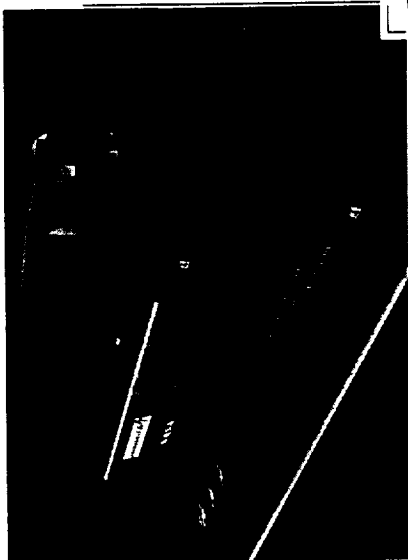
Industry

- LMMSS (Lead) Project Integration
- LMMSS Advanced Manufacturing Facilities Activation
- LMMSS NCAM Operations/Maintenance
- Technology / Process Development
- Large Structures Manufacturing



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NCAM



Federal, State, Industry and University Partnership
Initial Focus on Advanced Composite Materials Research/Production
Incorporates State of the Art Product Development Tools
World Class Manufacturing Capability

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Summary

Michoud Operations is expanding from metals into composites

- Over 25 years cryogenic structures experience
- Implementation on External Tank
- Leader in composite cryotank applications and LO2 compatibility

NCAM offers unique manufacturing capability for large structures

- Lockheed Martin partnered with academia and government